Remote GPU-Accelerated Synchrotron X-ray CT Data Processing Tool on the SPring-8 Data Center

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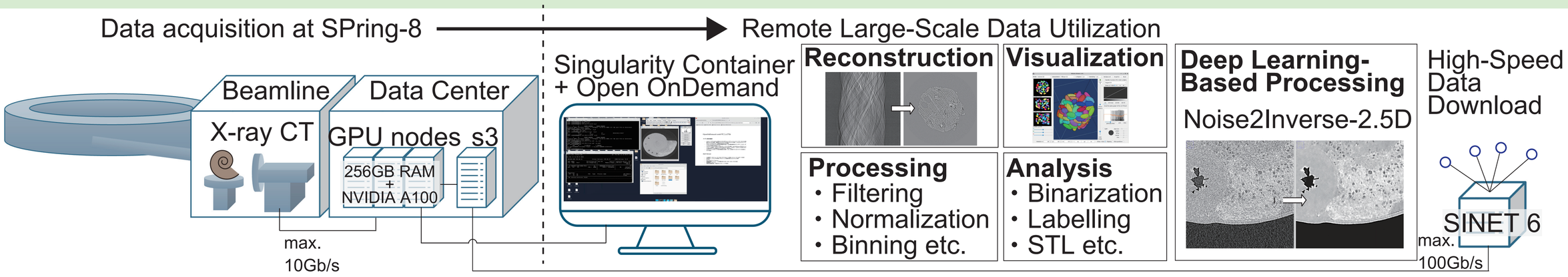


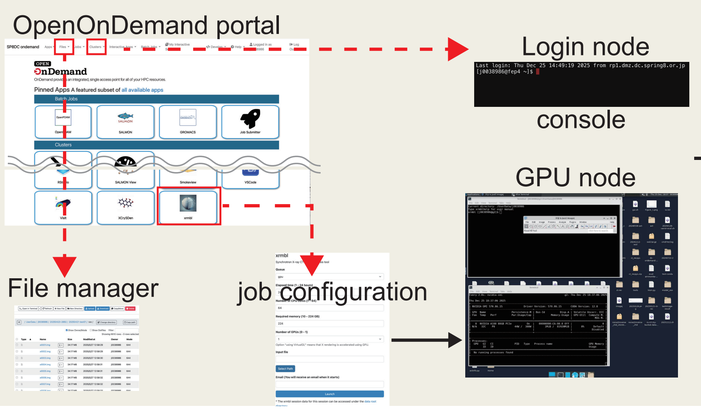
Motivation & Objectives

Recent technological advancements have enabled the rapid acquisition of massive datasets in short timeframes. The transfer of data for post-measurement processing and analysis often acts as a significant bottleneck. Crucially, image reconstruction is an indispensable step to transform raw CT data (projection images) into the cross-sectional images. Efficient processing and analysis require high-performance (and often costly) computing resources. In many cases, CT users do not have access to an adequate computational environment.To bridge this gap, we established a dedicated computational environment that utilizes cluster resources to streamline CT data workflows for the user community. The objective of this work is to providehighlights a real-world use case of HPC-driven user support at an analytical facility, showcasing the practical integration of large-scale computing into experimental science.

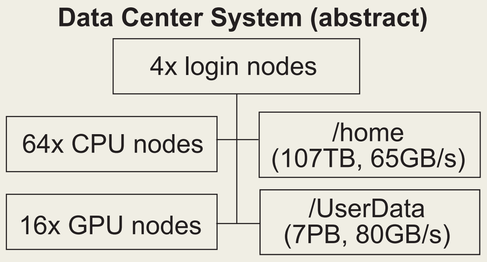
Typical data size of X-ray CT at SPring-8	4K camera (ORCA-Fire) (FOV 4432×2368 pixels) × 3600 projections × 100 msec exposure × 1 scan (no binning)	Auto-CT camera (SVS shr411XGE) (FOV 13000×400 pixels) × 6000 projections × 100 msec exposure × 1 scan, no binning (equivalent to 45 mm (diameter) × 1 mm (height) sample)
Scanning Time	10 minutes	15 minutes
RAW Image (16bit)	82 GB	60 GB
Reconstructed Image	**186 GB (32bit)**	**100 GB (16bit)**

SPring-8 Data Center

- High-bandwidth data transfer directly from the beamline (100Gbps at core network connected with SINET 6 and10Gbps at beamlines).
- High-performance computing (HPC) capabilities enabled by large-capacity memory and GPU (CUDA) acceleration.
- Remote desktop with OpenOnDemand, allowing GUI-based operation accessible from off-site locations.
- Provision of environment for custom apps using Singularity containers, offering compatiblity with other supercomputer systems.
- Accounts will be issued upon request for eligible users.



Data Center System (abstract)



GPU node

OS	Rocky Linux 8.7
CPU	2 × Intel Xeon Gold 6338 2.0GHz, 32C/64T
RAM	256GB (16 x 16GB RDIMM, 3200MT)
GPU	1 x Nvidia NVIDIA A100 (VRAM 80GB)

Storage quota

/home	100GB (for small data)
/UserData	50TB (for large data)

References
- https://dc-portal.spring8.or.jp/overview/
- Takaki Hatsui and Yasumasa Jochi, 2025. SPring-8/SACLA/Nanoterasu Info. 1(1), 18-21.

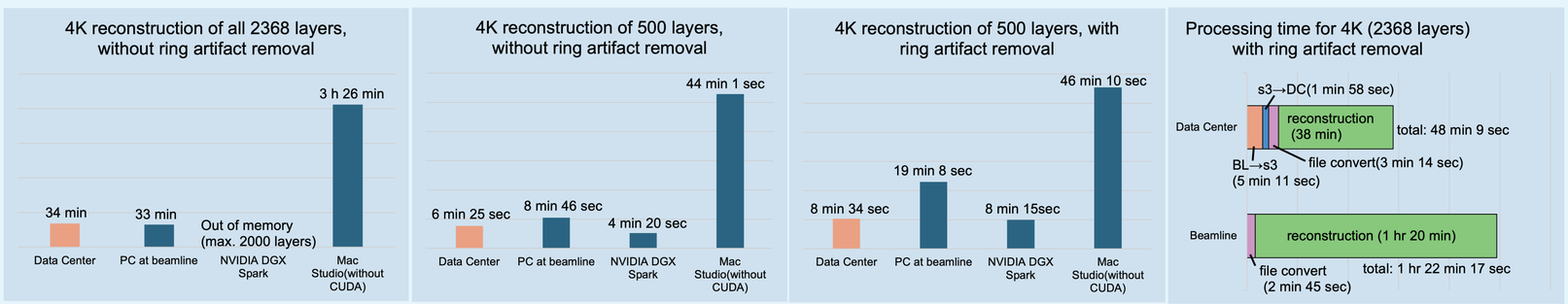
Data upload, download and sharing

- Inside SPring-8 campus, SSH port is available but limited to several networks.
- Both inside and outside SPring-8 campus, s3 storage can be used as a relay server. Temporal download URL and software such as s3 browser are available for ease.
- For small-sized data, up/downloading via OpenOnDemand portal is also possible.
- AutoCT data at BL28B2 can be transferred on datacenter without re-uploading.
- User access to /home and /UserData can be managed by acl.

CT image reconstruction and processing apps, and performance

Image reconstruction with SPring-8 standard software (ct-rec)

Convolution back projection (CBP) method with chesler filter and ring artifact removal (Algorithm 3 from Vo et al. (2018). Source codes are available from https://github.com/xrm-bl/ct-rec

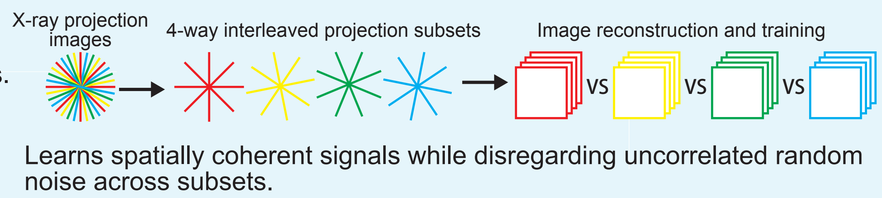


Processed material:
Acquired with 4K-resolution camera (ORCA-Fire), with FOV 4432×2368 pixels, × 3600 projections× 100msec exposure × 1 scan, no binning

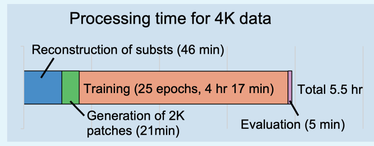
Machine specs:
- Beamline PC: Operated in BL28B2, CPU: Intel Xeon Silver 4210 (10 cores /20 thrreads, 2.20 GHz), RAM: 256GB, GPU: NVIDIA Quadro RTX8000, Storage: 2TB NVMe.M2 x4 RAID0
- NVIDIA DGX Spark (2025): CPU: 20 cores (10 Cortex-X925 + 10 Cortex-A725 Arm), RAM: 128GB unified memory, GPU: NVIDIA GB10, Storage: 4TB NVMe.M2
- Mac Studio (2023): CPU: M2 Ultra (24 cores CPU, 76 cores GPU, 32 cores Neural Engine), RAM: 192GB unified memory, Storage: 2TB SSD

Self-supervised denoising (Noise2Inverse-2.5D)

- High-Resolution Support: Handles up to 2K images; 4K processing via tiling.
- Core Model: Optimized 2.5D-Unet for sequential CT images.
- Streamlined Workflow: Automated pipeline for image splitting, reconstruction, and patching.
- Reliability: Checkpoint-based training to handle time-constrained environments.



Learns spatially coherent signals while disregarding uncorrelated random noise across subsets.



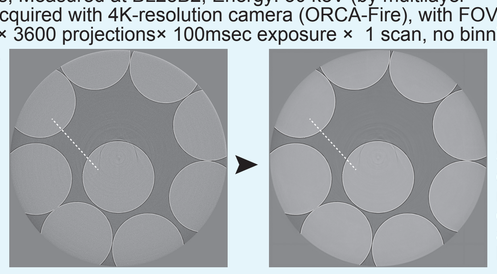
Data Extraction: 2216 × 2216 patches cropped from 4.4k full-resolution slices.

2.5D Architecture: U-Net input includes the target slice and ±5 adjacent layers (11 channels total).

Hyperparameters: 25 epochs, 200 slices/epoch, batch size 2, learning rate 0.25.

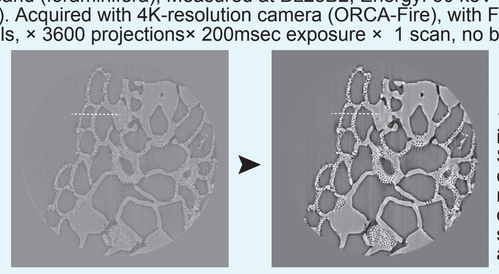
Application & Results

Sample: glass fibers, Measured at BL28B2, Energy: 30 keV (by multilayer monochromator). Acquired with 4K-resolution camera (ORCA-Fire), with FOV 4432×2368 pixels, × 3600 projections× 100msec exposure × 1 scan, no binning. Pixel size: 0.7 micron/px.

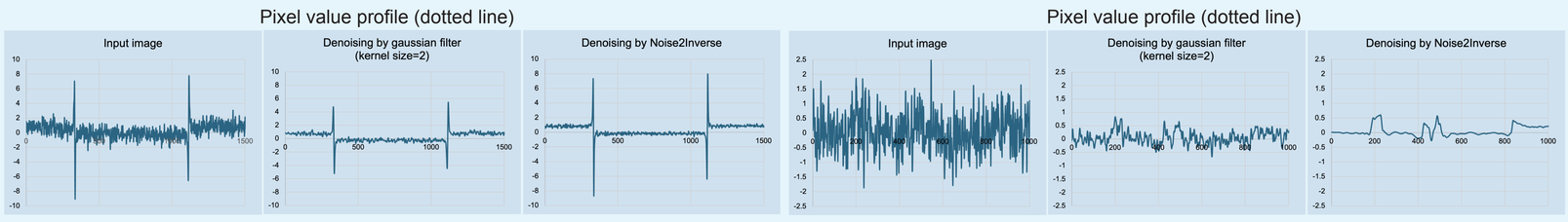


1.5-fold improvement in SNR, calculated by comparing the mean pixel values of the glass region against the air background.

Sample: a star sand (foraminifera), Measured at BL28B2, Energy: 50 keV (by multilayer monochromator). Acquired with 4K-resolution camera (ORCA-Fire), with FOV 4432×2368 pixels, × 3600 projections× 200msec exposure × 1 scan, no binning. Pixel size: 90 nm/px.



1.6-fold improvement in SNR, calculated by comparing the mean pixel values of the calcareous skelton against the air background.



Other analysis features & software

Analysis (CLI)	slice: SPring-8 image processing software.
Analysis (GUI)	ImageJ/Fiji: Handles 2,500 slices (4K, 32-bit TIFF)
3D visualization	ParaView: Surface and volume rendering
Support	Remote-accessible manual

Continuous updates based on user feedback

Future work

- Hardware Scaling: Utilizing multi-GPU clusters and high-capacity memory for ultra-large-scale data processing.
- Functional Extension: Broadening the analytical suite, specifically targeting segmentation workflows.
- Interface Optimization: Transitioning from CLI to an integrated GUI environment for better usability.

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